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lated till the fringes appears. As above, they are largest when c and c' are as nearly as possible coincident and vanish as horizontal fringes at the maximum; for the effective parts of c and c' are component halves of the same diffracted beam from the slit.

It is interesting to observe, since interference³ also occurs when one of the superposed spectra is inverted on a line parallel to its length, that such diffraction is demonstrable in case of homogenous light, even when the slit is absent.

A fuller report of this work has been presented to the Carnegie Institution of Washington, D. C.

¹ *Phil. Mag.*, 22, 118-129 (1911); *Carnegie Inst. Publ.*, No. 149, Chap. VI.

² *Physic. Rev.*, July, 1916; *Science*, 42, 841 (1915).

³ *Amer. J. Sci.*, 40, §4, 491 (1915).

ON THE INHERITANCE OF CERTAIN GLUME CHARACTERS IN THE CROSS *AVENA FATUA* × *A.* *SATIVA* VAR. KHERSON

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The investigation reported in the present paper¹ deals with the inheritance of certain characters of the flowering glumes in a cross between a wild oat *Avena fatua* and a cultivated variety (*Avena sativa*). The cultivated oat used is a selection from the Kherson variety. Both parent strains have been grown as pure lines for five years and are known to breed true.

The parent varieties used in this cross possess the following contrasting glume characters.

CHARACTER	AVENA FATUA	AVENA SATIVA VAR. KHERSON
Grain color	Dark brown or black	Yellow
Base of grain	Wild type	Cultivated type
Shattering	Shatters	Does not shatter
Awns	Heavy, twisted and geniculate awns on both upper and lower grains of a spikelet	None or an occasional awn on the lower grain. None on the upper
Pubescence	Thick pubescence on lateral and dorsal sides of callus on both grains	None or occasionally 1 or 2 hairs at the sides of the base of the lower grain
Base of grain		
Back of grain	Heavy pubescence on the back of both grains	None
Pedicle	Heavy pubescence on both grains	None

As shown in figure 2, the base of the grain or callus on the wild oat is expanded into a sucker-like ring. This large cleavage plane permits the grain to separate from the outer glumes very easily when mature. The cultivated grain (fig. 1) possesses a narrow contracted base and the grain does not shatter under ordinary conditions.

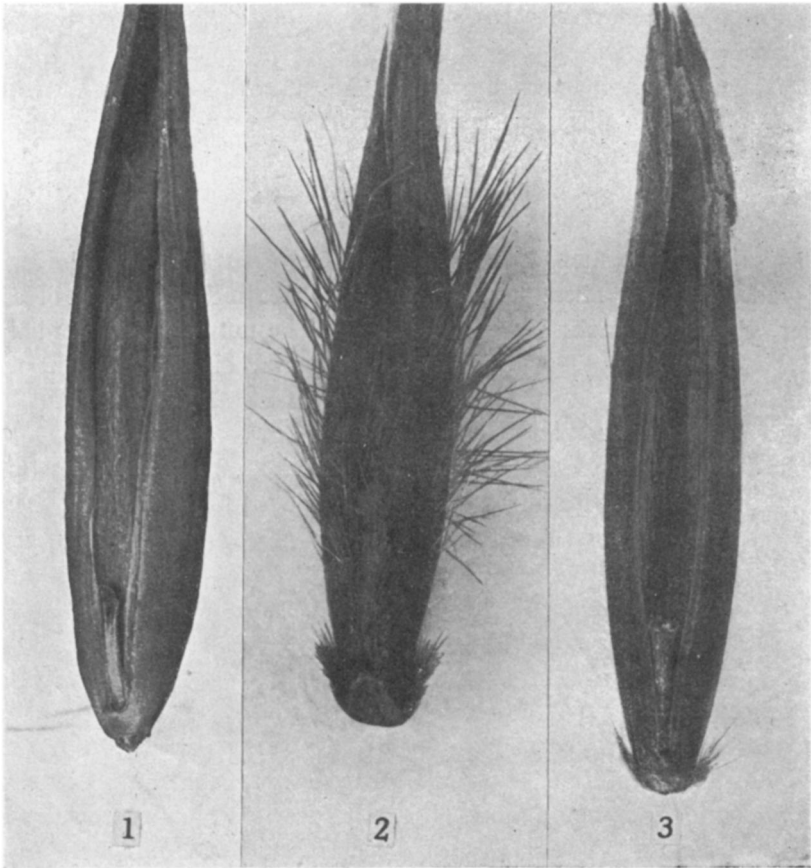


FIG. 1. VENTRAL VIEW OF THE LOWER GRAIN FROM A SPIKELET OF KHERSON OATS SHOWING THE CULTIVATED BASE OF THE GRAIN AND THE ABSENCE OF PUBESCENCE. $\times 8$.

FIG. 2. VENTRAL SURFACE OF THE LOWER GRAIN FROM A SPIKELET OF WILD OATS SHOWING THE WILD BASE, THE PUBESCENCE ON THE PEDICEL AND THE SIDES OF THE GRAIN. $\times 8$.

FIG. 3. VENTRAL VIEW OF THE LOWER GRAIN FROM AN F_1 PLANT SHOWING THE INTERMEDIATE BASE, PUBESCENCE AT SIDES OF THE BASE AND ABSENCE OF PUBESCENCE ON THE PEDICEL. $\times 8$.

In the F_1 generation the grain is brown in color but ordinarily not quite so dark as the pure wild. The base of the lower² grain in each spikelet is intermediate between the wild and cultivated condition (fig. 3).

The grain does not shatter. The base of the upper grain on each spikelet is like the upper grain of the cultivated variety. The F_1 grain is pubescent on the back of the lower grain of a spikelet but unlike the wild the upper grain of each spikelet is entirely free from pubescence. There is a tuft of hair at the sides of the base of the lower grain but none on the base of the upper grain. Medium strong to weak awns occur on the lower grain of most spikelets of the F_1 plants, but there are never any awns on the upper grain.

The F_2 generation consisted of 465 plants. A small F_3 generation was also grown. This consisted of short rows from 70 different F_2 plants.

The F_2 generation shows that the wild parent carries a factor for gray glume color as well as for black. It is also probable that the wild carries a gene for yellow color. The cultivated parent carries the factor for yellow color. These three colors segregate independently of each other, giving 12 black; 3 grey; 1 yellow. The numbers obtained were 347 black; 88 grey, 30 yellow, which is a very close agreement with expectation.

With regard to the base of the lower grain three types may be recognized: (1) the cultivated base (fig. 1); (2) the intermediate base like that found on the F_1 grain (fig. 3); and (3) the wild base (fig. 2). These three types appear in a 1: 2: 1 ratio on the F_2 generation. The observed numbers are 117 cultivated: 236 intermediate: 112 wild. The difference between the cultivated and wild base appears to be due to a single pair of genes. The heterozygous condition gives rise to the intermediate base.

The gene for the base of the lower grain segregates independently of the several color genes. For each of the three grain colors the plants with cultivated, intermediate and wild bases approach the 1: 2: 1 ratio.

There are, however, a number of characters which in the present cross are always associated with a particular type of base. In all there are seven pairs of characters which show this absolute correlation. The condition of each of these characters for the three types of bases on the lower grain is given in Table 1.

The present data are not sufficiently extensive to determine whether these several phenotypic characters are caused by the action of a single pair of genes or whether they are due to several pairs of genes very closely linked together. Nilsson-Ehle (1911) regards this group of characters as due to the presence or absence of a single inhibiting factor. In certain other crosses not yet completely analyzed but involving this same strain of *A. fatua* some of these correlations have been broken.

TABLE 1
CHARACTERS CORRELATED WITH THE THREE TYPES OF BASES ON THE LOWER GRAIN

CULTIVATED BASE	INTERMEDIATE BASE	WILD BASE
Cultivated base on the upper grain	Cultivated base on the upper grain	Wild base on the upper grain.
Absence or almost complete absence of awns on the lower grain	Medium awns on the lower grain of some spikelets	Very heavy awns on the lower grain of every spikelet.
Total absence of awns on the upper grain	Total absence of awns on the upper grain	Very heavy awn on the upper grain of every spikelet
Absence of pubescence on the pedicel on the lower grain.	Absence of pubescence on the pedicel on the lower grain	Heavy pubescence on the pedicel on the lower grains.
Absence of pubescence on the pedicel on the upper grain	Absence of pubescence on the pedicel on the upper grain	Heavy pubescence on the pedicel on the upper grain
None or sometimes very slight pubescence at the sides of the base of the lower grain	Medium heavy tuft of hair at the side of the base of the lower grain	Heavy pubescence on all sides of the base of the lower grain
No pubescence on the base of the upper grain	No pubescence on the base of the upper grain	Heavy pubescence on all sides of the base of the upper grain

This and other facts have led the writer to believe that some of these characters at least are controlled by separate genes.

Characters Showing Partial Linkage.—Two characters have been discovered in this cross which apparently show partial linkage with other genes. These characters are (1) pubescence on the back of the lower grain and (2) pubescence on the back of the upper grain. These two characters are inherited independently of each other but the phenotypic appearance of the latter character is dependent upon the presence of the former gene in the same zygote.

In the F_2 generation the plants which have pubescence on the back of the lower grain segregate from those lacking this character in a 3 to 1 ratio. The observed numbers are 347 pubescent to 118 smooth. This character further segregates independently of the type of base on the lower grain.

On the other hand there is a very close relation between the presence and absence of black color and the presence and absence of pubescence on the back of the lower grain. The observed numbers are shown in table 2.

There is an almost absolute correlation between the presence of pubescence on the lower grain and the black color. However, two black plants were found which lack this pubescence entirely. The grain from these two plants has been carefully examined and no evidence of

TABLE 2

RELATION OF THE PUBESCENCE ON THE BACK OF THE LOWER GRAIN TO THE COLOR OF THE GRAIN

	BLACK		NON-BLACK	
	PUBESCENT	SMOOTH	PUBESCENT	SMOOTH
Observed Number.....	345	2	0	118

pubescence could be found. No plants with pubescent non-black grains have been found in this cross. However, in certain other crosses in which this same wild was used, a few non-black pubescent plants have been found.

While the present data are hardly sufficient to prove the point, it seems very probable that we have here a case of partial linkage. Although a straight F_2 generation is not the best kind of data with which to study linkage, certain points can nevertheless be made out.

As the observed figures stand they represent a coupling series in which the gametic ratio (in Bateson's sense) is approximately 240 : 1. If the present supposition is correct we might reasonably expect that some non-black pubescent individuals should appear in the 465 plants. Their absence is probably due to a chance fluctuation. If we may assume that one such individual is to be expected in 465, this will make a total of three crossover plants and the gametic ratio would be approximately 150:1. This means that instead of appearing in equal numbers the different classes of gametes will be formed in the ratio 150 black, pubescent:1 black, non-pubescent:1 non-black, pubescent:150 non-black, non-pubescent.

In regard to the gene for pubescence on the back of the upper grains it will be remembered that the absence of pubescence in this case is dominant over its presence. In the F_2 generation there are 378 plants without pubescence (smooth) to 87 which are pubescent on the upper grain. The ratio here is not 3 to 1, but 4 to 1. Likewise the relation between this gene and the gene for pubescence on the back of the lower grain gives a 9:3:4 ratio. No individuals occur which are smooth on the lower grain and pubescent on the upper. Apparently the gene for pubescence on the lower grain acts as a basic pubescence factor in a manner quite similar to the color factor (C) in mice, rabbits, sweet peas and many other organisms. In the absence of the factor for pubescence on the lower grain the factor for pubescence on the upper grain remains inactive.

The fact that this basic pubescence factor is linked with the black color factor disturbs the phenotypic ratio of the non-black plants when

the character pubescence on the back of the upper grain, is correlated with other characters.

Table 3 shows the relation between this character and the type of base on the lower grain. In this table the cultivated and intermediate types of base are grouped together under the term 'cultivated.'

It is seen at once that there is distinct evidence of linkage between these two genes. Since the ratio in the non-black plants is disturbed by interdependence of two genes, it is necessary, in considering the question of linkage, to use the data from black plants only as given in the second line of the table.

Calculating the probable gametic ratio necessary to produce such an F_2 generation (using the black plants only) it is found that this ratio is approximately 65 to 1.

To sum up the main features of the present hypothesis, it is found that the gene for pubescence on the back of the upper grain segregates independently of the gene for pubescence on the back of the lower grain.

TABLE 3
RELATION BETWEEN THE PUBESCENCE ON THE BACK OF THE UPPER GRAIN AND THE CHARACTER OF THE BASE

	CULTIVATED		WILD	
	SMOOTH	PUBESCENT	SMOOTH	PUBESCENT
All plants.....	352	2	27	85
Black plants only.....	257	2	3	85

However, the former gene is unable to produce a pubescence unless the factor for pubescence on the lower grain is present in the same zygote. The gene for pubescence on the back of the lower grain shows partial linkage with the gene for black color. The gametic ratio is apparently about 150 to 1. The gene for pubescence on the back of the upper grain is partially linked with the gene for the wild base. The gametic ratio in this case is approximately 65 to 1. It is very probable that these gametic ratios will be changed somewhat when larger numbers of individuals are available. It is believed that the present assumption represents the essential facts.

The brilliant work of Morgan and his collaborators upon linkage and its relation to the chromosome theory of inheritance makes it exceedingly attractive to point out the possible relation of these genes to the chromosomes. In the first place it has been shown by Nilsson-Ehle (1909) and partly by the present work that the three pairs of color genes segregate independently of each other. It may, therefore, be supposed that

they lie in separate chromosomes. Further the gene for the character of the base of the grain segregates independently of the color genes. It, therefore, probably lies in a fourth chromosome. The seven characters given in table 1 are very closely if not absolutely linked with the character of the base. If these seven characters may be supposed to be due to separate pairs of genes these must lie in this fourth chromosome.

Still a ninth pair of genes is located in this fourth chromosome, viz., that for smoothness (lack of pubescence) on the back of the upper grain. This gene is apparently located at a slight distance from the group discussed above since it shows about 1.5% of crossovers with the members of that group.

The gene for pubescence on the back of the lower grain is linked with the gene for black color and is, therefore, to be regarded as located in the same chromosome. The per cent of crossovers between these two genes is probably less than 0.7%.

¹ This is an abstract of paper No. 95 from the Biological Laboratory of the Maine Agricultural Experiment Station. The complete paper is now in press in *Genetics*.

² A spikelet of common oats usually bears two grains. The larger of these is called the "lower" grain and the smaller one the "upper" grain. The upper grain is articulated with the lower by means of a short pedicel.

A COMPARISON OF THE RATES OF REGENERATION FROM OLD AND FROM NEW TISSUE

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In determining the factors of regeneration one of the questions that arises is the extent to which rate of growth of the new organ is controlled by the character of the cells at the cut surface. Is regeneration wholly a matter determined by the characteristics of the local cells or is the process under more central control? If the former is true, change in the condition of the cells near the cut surface should modify the rate of regeneration, if the latter, such change does not necessarily mean change in rate.

The present study consists of a comparison of the rate from newly regenerated tissues with that from old tissues. When a portion of the tail of a frog tadpole is removed by a transverse cut there is near the cut surface a considerable degree of reorganization of the cells which are to give rise to the new organ. If, before the completion of regeneration, a second removal is made the regeneration will be from new cells if the second cut is distal to the level of the first and from old cells if it